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DEVICE FOR TRACKING AND LOCATING OBJECTS

Background of the invention

The invention relates to a system for tracking and locating objects arranged in a storage space, comprising:

- a transponder associated to each object, equipped with an identification code of the object concerned,
- tracking means able to locate a given transponder from a signal emitted by this transponder,
- an indication system physically independent from the objects to be tracked and from the transponders and equipped with indicating means arranged in the storage space.

State of the prior art

The problem of searching for an object among others in a storage space has given rise to numerous devices implementing various tracking and locating methods. Most of the processes consist in placing the objects according to preset rules so as to be able to extract them by applying the same methodology.

The introduction of electronic passive label reading devices has enabled the dependability of storage systems to be considerably improved, the most commonly used label today being the "barcode" label. But such devices do not dispense with having to apply a strict preliminary sorting methodology.

More recently, technology has made implementation of active transponder labels possible. We will call here transponder any receiver transmitter responding automatically to an external signal from a transmitting beacon. The transponder is called active when it carries or stores sufficient energy for its operation. The document FR-A-2,701,142 describes a system of this type designed for identification, searching and indication of objects placed in random manner in a storage space. Each object is provided with a label comprising an infrared signal sensor, a logic comparison circuit of

the received signals with a reference signal stored in a memory, and a light emitter controlled by the logic circuit. In response to a search signal emitted by a search beacon, the corresponding label indicates its position by emitting a light signal enabling a person to locate it. According to a variant of this type of system described in the document EP-A-0,794,507, the label manifests itself by emitting a sound.

Due to their very principle, these technologies require sophisticated and therefore costly labels carrying or storing the energy sufficient to bring themselves to the attention of the human senses. To overcome the drawbacks proper to active labels, passive transponder labels have been developed. The transponder is called passive when its receiver part is able not only to receive the signal from the beacon but also to draw from this signal the energy necessary for operation of the transponder. Naturally the signal emitted by a label of this type is much less powerful than the one that can be emitted by an active transponder, so that it is difficult to achieve emission by the label of a signal directly perceivable by a person, at least at a great distance. This is why locating systems implementing passive transponders are equipped with transponder signal receiver beacons and a reading interface indicating the co-ordinates of the object bearing the label corresponding to the search criteria. The document EP-A-0,794,507 describes a portable system comprising the emitter beacon, the receiver beacon and the interface, the latter emitting an audible or visual signal varying with the distance separating the interface from the transponder so as to guide the person holding the interface in his search for the object bearing the label. In an alternative embodiment described in the same document, the device comprises locating markers equipped with an energy source and a receiver and arranged in the area where the objects to be searched are located. When the passive transponder associated to the searched object emits a signal, the markers located in its neighbourhood receive this signal and emit a sound enabling the person to locate the part of the storage area where the searched object is located. Provision is even made for the markers to transmit to the portable system information indicating the distance between the marker and the transponder.

Such a device does however give rise to some problems of implementation. Firstly if the power of the signal emitted by the passive transponder is not properly adapted, it may

activate several markers placed in its neighbourhood, and maybe even all the markers situated in the storage area, which means that the transmitted information no longer has any relevance whatsoever, or on the contrary it may not activate any markers at all. In practice, these risks impose narrow operating ranges for the transponders and markers, ranges that are all the more difficult to respect as passive transponders rely for their energy on the power of the electromagnetic signal supplied by the emitter beacon integrated in the portable questioning device, a distance that itself varies with the distance separating the beacon from the transponder.

Consequently, the arrangement of the beacons and markers with respect to the transponders has to be studied particularly carefully so as to meet certain space criteria, which imposes pointless constraints as to the arrangement of the objects in the storage space. Moreover, each marker has to be provided with a processing device of the signals coming from the passive transponders that is sufficiently sophisticated to make a discrimination between the signals coming from nearby labels and the signals coming from distant labels, thus resulting in a high cost.

In a more general manner, the device has the drawback of materially combining the means for receiving the signals emitted by the labels with the audible or visual indicating means. However the spatial density and location necessary to perform the label location function does not generally bear any relation to that required for label indication. If for example a radiogonometry algorithm is applied, it is possible under certain conditions to determine a position in a plane from three receivers with an excellent spatial resolution within a triangle formed by the receivers. If no audible or visual indicating means are provided within the triangle formed by the three receivers, with a density corresponding to the spatial resolution of the location, a large part of the information is lost. In other words, the markers achieve a poor compromise between the location requirements and the indication requirements.

Object of the invention

The object of the invention is to enable objects bearing transponders to be located in an

area of any size, in a manner that is simple and compatible with the technology of both active transponders and passive transponders.

According to the invention, this problem is solved by means of a system for tracking and locating objects arranged in a storage space, comprising:

- a transponder associated to each object, equipped with an identification code of the associated object,
- tracking means able to locate a given transponder from a signal emitted by this transponder,
- an indication system physically independent from the objects to be tracked and from the transponders and equipped with indicating means arranged in the storage space,

and that comprises in addition

- a database enabling one or more of said indicating means situated in proximity to said location to be determined for each location in the storage space,
- control means able to question the tracking means on the location of a transponder corresponding to a given identification code, to consult the database to determine said indicating means corresponding to the location determined by the tracking means and to activate said indicating means situated in proximity thereto.

The expression "physically independent" means that materially the location of the indication system does not vary when the objects are moved in the storage space.

Preferably the database enables one or more of said indicating means to be determined for each location in the storage space enabling an access route to said location to be marked out and the control means are able to activate said indicating means marking out an access route between a preset point and the indicating means situated near to the transponder. Such an arrangement enables the searched object to be located easily in a storage space of large dimensions and complex structure. It also enables efficient tracking independently from the power of the signal emitted by the indicating means.

The flexibility of implementation of the invention is enhanced if the indication system is physically independent from the tracking means.

In its principle, and this is a decisive advantage, the invention is applicable to any type of transponder, which leaves a great flexibility in hardware management. Naturally the invention is particularly advantageous when the transponders are passive transponders since it enables the power insufficiency of this type of transponder, which limits the degree of perception directly accessible to human senses, to be compensated. In this case, the tracking means are provided with means for emitting a call signal and at least one of the transponders is a passive transponder equipped with receiving means for receiving said call signal and with emitting means, the receiving means being able to extract from the signal received the energy necessary for activation of the emitting means.

Preferably the tracking means comprise a plurality of receiver beacons, each receiver beacon having a set spatial receiving field, and the control means are connected to the receiver beacons of the tracking means by means of a multiplexer. This enables the complexity of the hardware constituting the system to be limited and certain signal processing units, in particular the modem function, to be grouped up-line from the multiplexer. In a similar manner, the tracking means can comprise a plurality of emitter beacons, each emitter beacon having a set spatial receiving field, and the control means be connected to the emitter beacons of the tracking means by means of a multiplexer. Alternatively the control means can be connected to the receiver and/or emitter beacons of the tracking means by means of a network, this arrangement then presenting the advantage of simultaneous questioning of all the beacons resulting in a reduction of the search time in installations of large dimensions.

Preferably the emitted and received signals are electromagnetic signals. The signals can for example be infrared or hertzian signals.

The beacon network can be more or less dense, depending on the topography of the storage space, the spatial resolution sought for and the location method.

Various methodologies can be implemented to determine the position of a given

transponder with respect to the beacons. In the case of radiofrequency signals for example, it is known that the power of the signal received by the antenna constituting the transponder receiver is a function of the distance between the latter and the antenna of the emitter beacon. It can therefore be provided for the transponder to comprise a radiofrequency receiver, and means for measuring the power of the call signal emitted by the emitter beacon, and for it to emit a response signal in response to the call signal from the emitter beacon encoding the value of the power of the call signal as received by the transponder, for example in digital form. Alternatively, the emitter beacon can itself measure the energy or power of the signal absorbed by the transponder and deduce therefrom at what distance it is located, this solution providing the advantage of being able to be implemented with standard transponders.

A binary position determining method can also be implemented by analysing the configuration of the antennas that "see" or don't "see" the transponder;

A conventional radiogonometry method using several spaced apart radiogonometers of known position can also be implemented to determine the position of the source constituted by the label transponder activated by an emitter beacon.

Depending on the resolution and dependability required, several of the foregoing methods can be combined.

The type of indicating means has to be adapted to the environment of the storage space. Preferably the indicating means comprise display means such as light-emitting diodes or LCD screens, and/or acoustic emitting means.

Brief description of the drawings

Other advantages and features of the invention will become more clearly apparent from the following description of an embodiment of the invention given as a non-restrictive example only and represented in the accompanying drawings in which:

- figure 1 represents a schematic diagram of operation of the invention;
- figures 2a to 2c represent different operating modes of the antennas used in the invention;
- figure 3 represents a second embodiment of the invention.

Description of a preferred embodiment

With reference to figure 1, a collection of objects 10 is arranged on a shelf 12 constituting a storage space.

Each object is equipped with a label 14 comprising a passive transponder 16 equipped with an antenna able to take the form of a coil, and an identification code of the associated object. The term label will be used here to designate a material support of any form that can be materially fixed, either removably or not, onto the object to which it is associated. This type of label, also called tag, is well known to the man of the trade.

Antennas 18 formed by coils are arranged in such a way as to scan the storage space 12. Each of the antennas 18 is connected to an antenna adapter amplifier 20.

A modem 24 is connected to the antenna amplifiers 20 by means of a multiplexer demultiplexer unit 22. The set-up is controlled by a microcontroller 26 equipped with a man-machine communication interface 28.

The shelf 12 is equipped with indicator lamps 30 with light-emitting diodes situated immediately next to the objects to be identified 10. A database 32 making one or more areas of the storage space 12 correspond to each indicator lamp 30 is associated to the microcontroller 26. The microcontroller 26 controls means 34 for commanding lighting of the indicator lamps 30. There are not necessarily as many indicator lamps 30 as objects 10 as the indicator lamps 30 are physically independent from the objects 10. The density of indicator lamps 30 should be chosen according to the space resolution of the location and the requirements of the application. Under certain circumstances, there will be more indicator lamps 30 than objects 10, in particular when some of the stored

objects 10 are bulky or the storage space is partly empty. In other cases, the number of objects 10 will be greater than the number of indicator lamps 30, and it will be up to the person to look for the object 10 by hand in the immediate neighbourhood of the indicator lamp 30. Provision can moreover be made for all the indicator lamps 30 situated around the area in which the searched object 10 is located to be lit simultaneously by the microcontroller 26 for ease of marking out the search area.

The antennas and transponders technology depends on the requirements of the application. In technologies using for example a frequency of 13.56 MHz or 125kHz, the maximum distance between the antenna and the label usually ranges from a few mm to about 1 metre. In the 4.5 GHz technology, the reading distance can reach several metres with an active label. The spatial arrangement of the antennas depends on the application. Their fields of action can be totally distinct, as illustrated by figure 2a, or overlap partly as illustrated by figure 2b, or be organised to allow a dichotomizing search as illustrated by figure 2c.

The position of the object can be determined more or less precisely by various known methods that can be used alternatively or in combination.

According to a first method, the position of a label 14 is determined along a co-ordinate axis by equipping each end of the section concerned with an emitting antenna 18. Each antenna 18 successively emits an electromagnetic field whose amplitude on the axis of the coil decreases as a function of the distance to the plane of the emitting antenna 18. The position of the selected label 14 and therefore of the searched object on this axis is determined by analysing the load variation of the receiver coil of the transponder 16 seen by each of the two coils.

According to a variant of this method, the labels 14 are themselves able to measure the induced field received and to communicate it to the transmitter by digital encoding means.

According to a second method, a network of beacons is installed each having a given

field of action along an axis. The position of the antenna along an axis is determined by analysing the configuration of the beacons that "see" or don't "see" the label, using a binary approach. It is determined step by step for each successively activated beacon whether the searched label responds to the signal from the beacon, and the position of the label is then determined from the configuration of the beacons that were able to communicate with it.

The procedures for locating in a plane can be deduced from the foregoing either by splitting the plane into adjacent parallel linear strips or by splitting it in matrix manner with two networks of perpendicular linear strips.

The system operates in the following manner.

A requester 36 supplies the microcontroller 26 with a search order for a particular object either by entering the code of the object to be searched directly on the interface 28 or by identifying it in a manner enabling the microcontroller 26 to find the associated code by searching in the database. The microcontroller 26 actives the antennas 18 according to a protocol which may be of any kind until it identifies the antenna or antennas by which the searched code has been acknowledged. The modem 24 performs transformation of the orders from the microcontroller 26 into analog activation of the antennas 18 and conversion of the analog signals received into digital signals understandable by the microcontroller 26. The microcontroller 26 interprets the results supplied by the antennas 18 and determines the position of the searched object from data stored in the database 32 by an algorithm which may be of any kind. It informs the requester 36 via the interface 28 and commands activation of the indicator lamp 30 the nearest to the determined position by means of the lighting control unit 34. Should the search be fruitless, the interface 28 supplies a visual or audible message indicating that the object cannot be found.

According to an alternative embodiment, the microcontroller 26 commands activation of a set of indicator lamps 30 enabling an access route to be marked out between the communication means and the object. Lighting of the indicator lamps can be continuous

or animated so as to give a visual impression of movement leading to the searched object. In the case where the man-machine communication means 28 is itself mobile, it is itself equipped with a transponder label so that the microcontroller can also determine its position in the storage space and command selective activation of the indicator lamps marking out the route going from the mobile communication means to the object.

The database 32 associating the indicator lamps 30 to areas of the storage space can be constituted by learning if the indicator lamps are themselves equipped with transponder labels.

Figure 3 represents a second embodiment of the invention that differs from the first embodiment by the fact that the beacons 18 are networked by means of a network control 22a. This naturally enables quicker access to the relevant information when the number of beacons increases.

The above description is given as a non-restrictive example only and various variations are possible. In particular, the invention can also be implemented with active transponders whose own power source is not used to obtain a direct manifestation from the label but to amplify the signal emitted to the antennas. This variant enables the number or sensitivity of the transmitter and receiver beacons to be limited.

The tracking system according to the invention also enables the searched document to be accessed immediately, makes filing of the extracted document easier, and facilitates filing of new documents.

In the case of filing a known document, the tracking system will therefore have the role of indicating to the user the place where the document has to be filed. Information on the place where the document to be filed has the right to be located has for this purpose been entered in the database 32, for example:

- the only authorised place is the one the file occupied before it was extracted,
- a classification algorithm determines the appropriate place for filing by analysing the places occupied by the other documents.

Several filing procedures can be envisaged:

- the user selects the document to be filed via software,
- the user has the document to be filed identified by the system by placing it near a specific or ordinary inductive loop (reader). The use of a mobile reader can be envisaged.

The locating system is able to perform the reverse tracking operation, i.e.:

- from the document code, indicating the location where the document is to be filed,
- warning the user who places the document in the wrong place by a light and / or audible alarm.

In the case of filing a new document, the user enters the characteristics of the new document in the database 32. The database 32 or an associated software chooses the place where the document has to be filed and indicates it to the user. The system then checks that the new document (recognisable by a code unknown up till then) is in fact inserted in the right place.

Checking the filing is performed by continuous checking of the state of the database 32 by the system and can inform the user of the manual inputs and take-outs of documents, of the coherency of the filing, of faults observed for example unknown label codes or abnormal reading errors (able to anticipate an operating malfunction).

The locating system according to the invention is therefore able to locate not only a document identified by its transponder code but also the place where a document identified by its transponder code or other information has to be filed according to a predefined logic.

When a document is moved, the system can track the document so long as it remains in the field of a loop. However, depending on the distribution of the loops, the user can deduce information concerning the position of the document even if it has left the loop field. For example, passing and the direction of passing through a door can be deduced

from the successive positions of the object in the field of loops arranged on the doorway.

According to a development of the invention, prevention loops can be arranged at library exit doors. When a lent book is "taken off" the shelf, defined information is written to the label. The sentry loop situated at the exit from the premises can therefore detect in its field the labels that are not authorised to be "taken out".

In the case of read-only labels, the authorisation information is recorded at management computer level and the purpose of the sentry reader is to communicate the codes of the labels passing through its field to the computer. The computer then triggers the alarm if required.

In the last two examples, the successive positions of the objects are analysed with respect to the storage space which is then extended to the circulation spaces, which enables the probable position of the object to be deduced at any time.

Another application is that of searching for a lost object. When a file is missing from its usual location, it is sometimes unable to be found as it is camouflaged under a pile of documents. A mobile reader can then enable it to be located. The identification code searched by the locating system can be supplied to the reader via a link with or without contact.

The locating procedures described do not exclude the use of other procedures. Label locating can be performed for example by radiogonometry from three radiogonometers bounding the storage space. The transmitter and receiver antennas can be spaced apart from one another.